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(54) **CYCLONIC VACUUM CLEANER RIBBED CYCLONE SHROUD**

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B01D 45/12 (2006.01)

(52) **U.S. Cl.** **95/271**; 55/337; 55/429; 55/459.1; 55/DIG. 3

(58) **Field of Classification Search** .... 55/426, 55/429, 337, 459.1, DIG. 3
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,195,835 B1	3/2001	Song et al.	
6,341,404 B1	1/2002	Salo et al.	
6,521,006 B2	2/2003	Park et al.	
6,818,032 B2	11/2004	Bilek et al.	
7,065,826 B1	6/2006	Arnold	
7,152,277 B2	12/2006	Jung et al.	
2005/0138763 A1	6/2005	Tanner et al.	
2008/0257161 A1 *	10/2008	Read	96/220

OTHER PUBLICATIONS

International Search Report mailed Jan. 29, 2010, PCT/US09/59960.

* cited by examiner

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(57) **ABSTRACT**

A vacuum cleaner cyclone separator having a cyclone chamber with an air inlet and an air outlet. The cyclone chamber directs an airflow into a cyclonic pattern to remove a first amount of debris from the airflow. A filter shroud is located within the cyclone chamber and separates the air inlet from the air outlet. The filter shroud includes an air-pervious filter surface adapted to allow the airflow to pass from the air inlet to the air outlet and remove a second amount of debris from the airflow. One or more protrusions are associated with the filter surface, and configured and dimensioned to direct at least a portion of the airflow passing generally parallel to the filter surface away from the filter surface before passing through the filter surface. A dirt collection assembly having a cyclone separator and a method for using a cyclone separator are also disclosed.

22 Claims, 3 Drawing Sheets

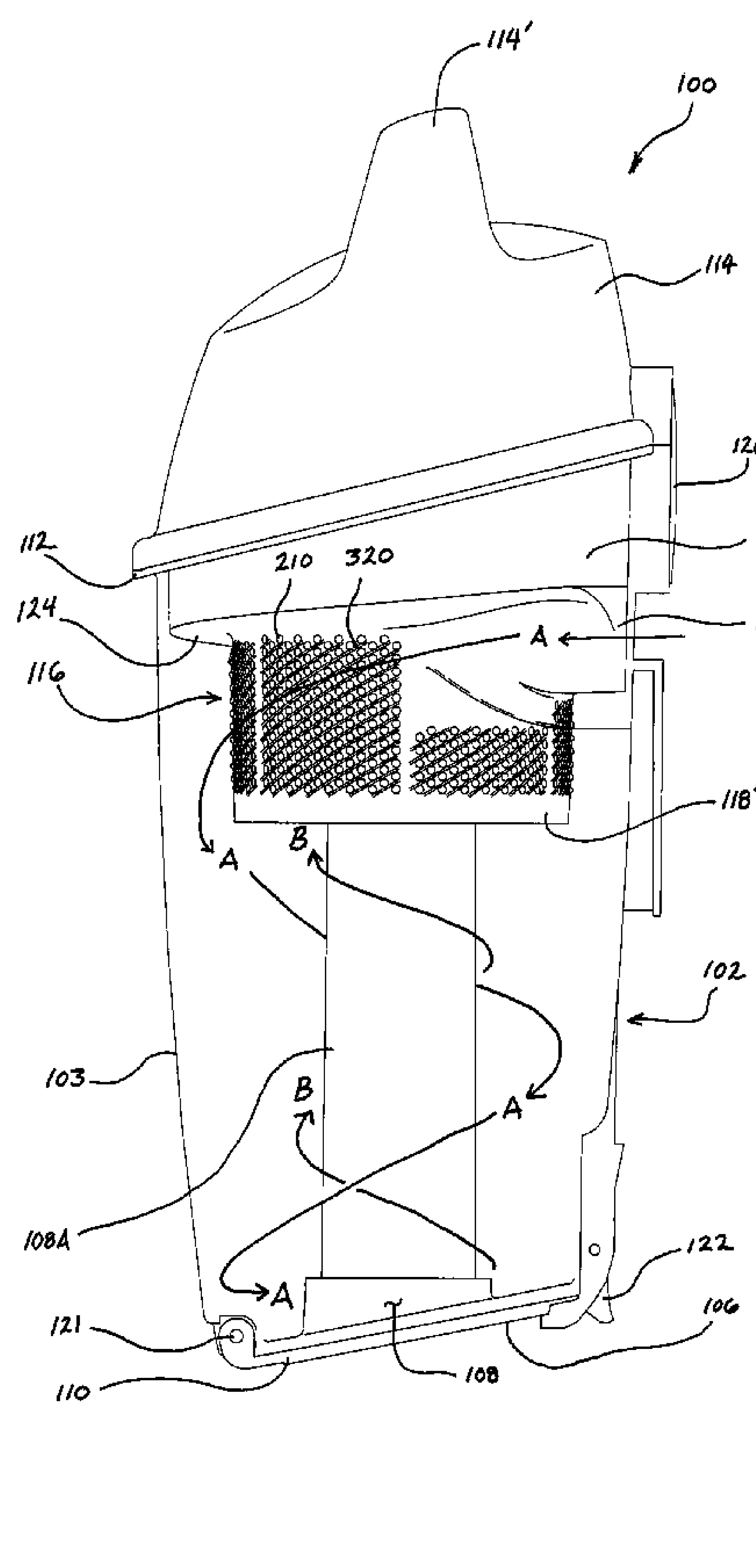
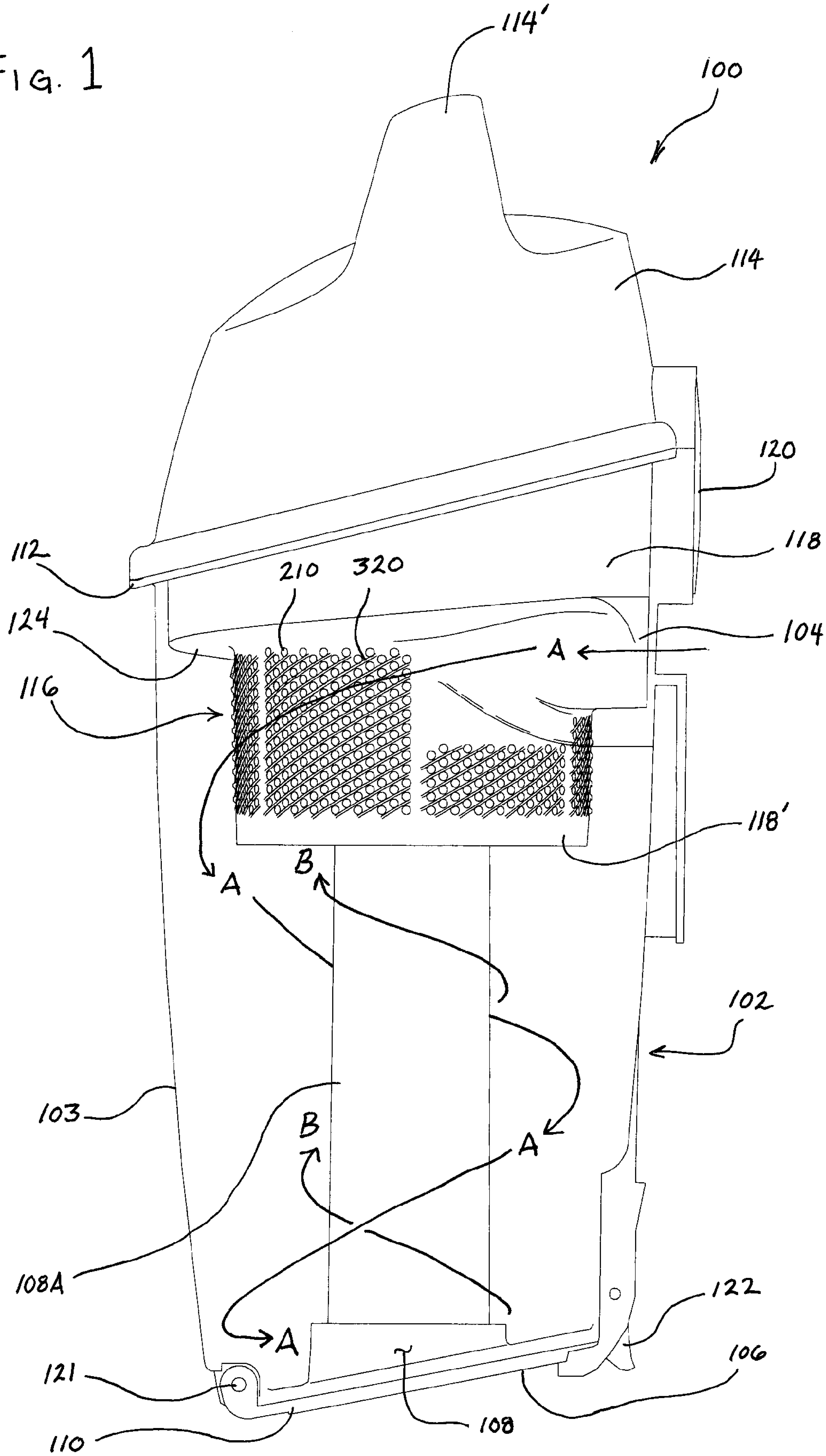


FIG. 1


114'
100
114
120
118
112
210
320
124
104
A
116
118'
A
B
102
103
B
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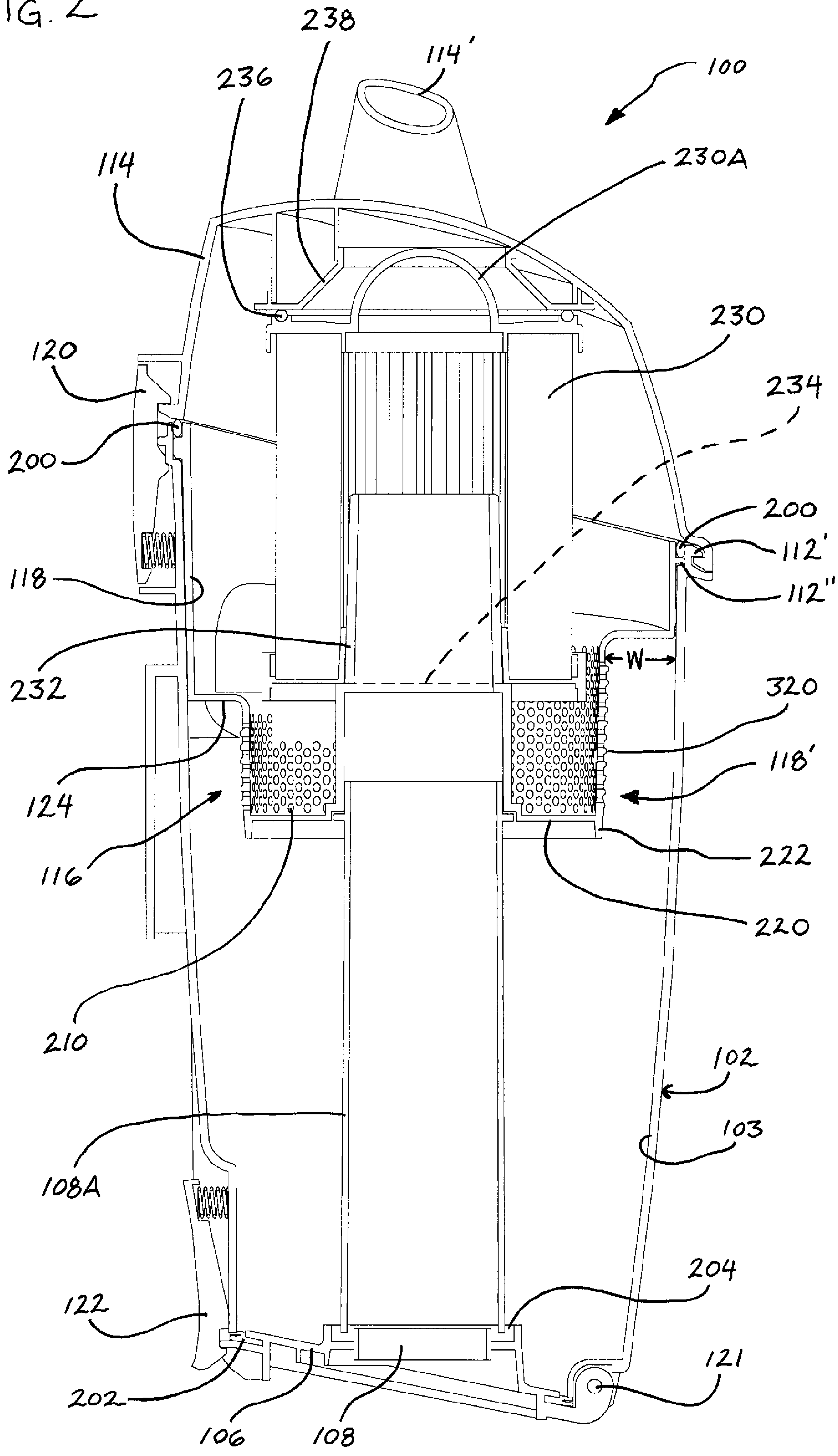
108A
A
122
106
121
108
110

FIG. 2



238
114'
100
236
114
230A
230
120
234
200
200
112'
118
112''
232
W
320
124
118'
116
222
220
210
102
103
108A
204
122
121
202
106
108

FIG. 3

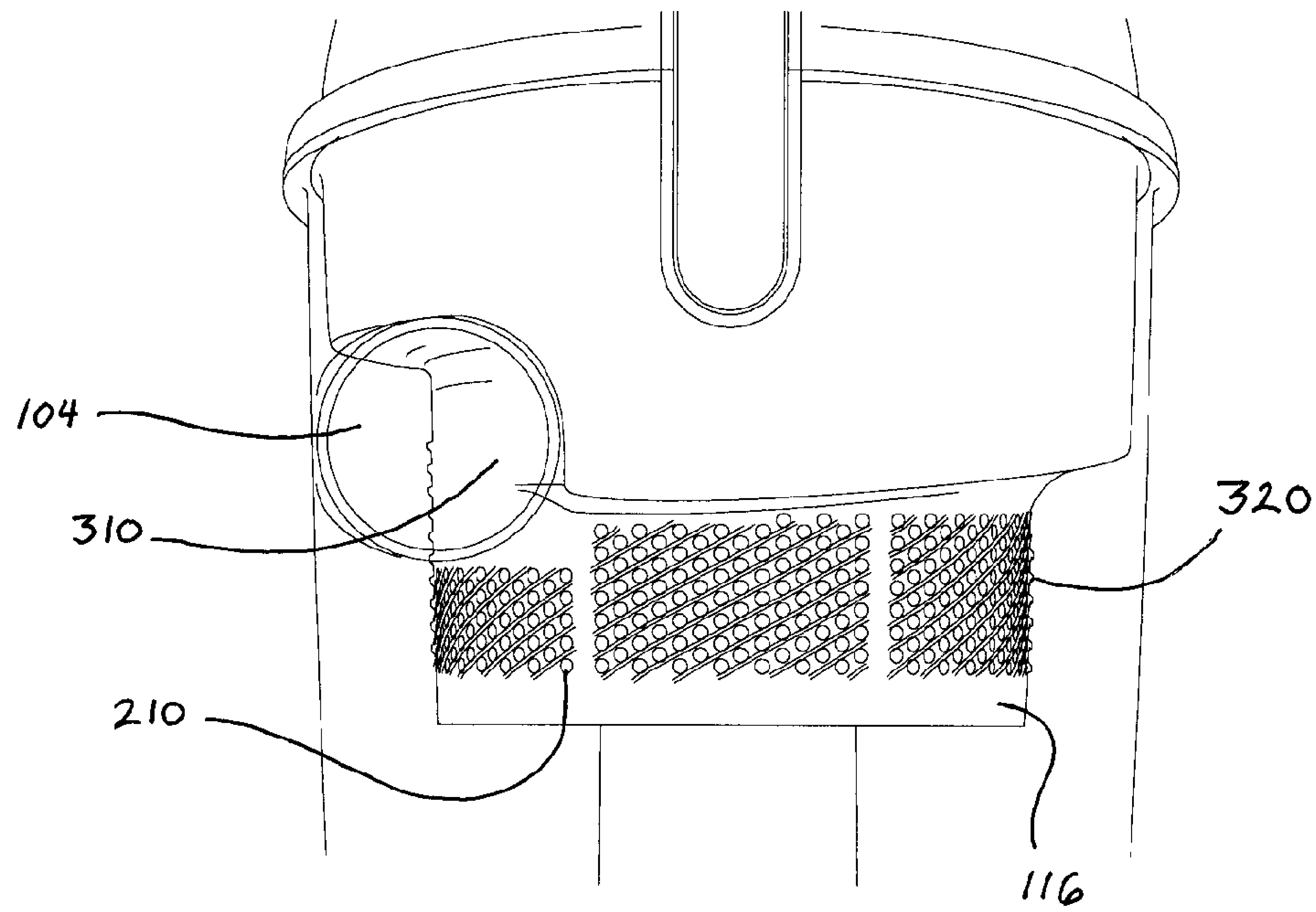
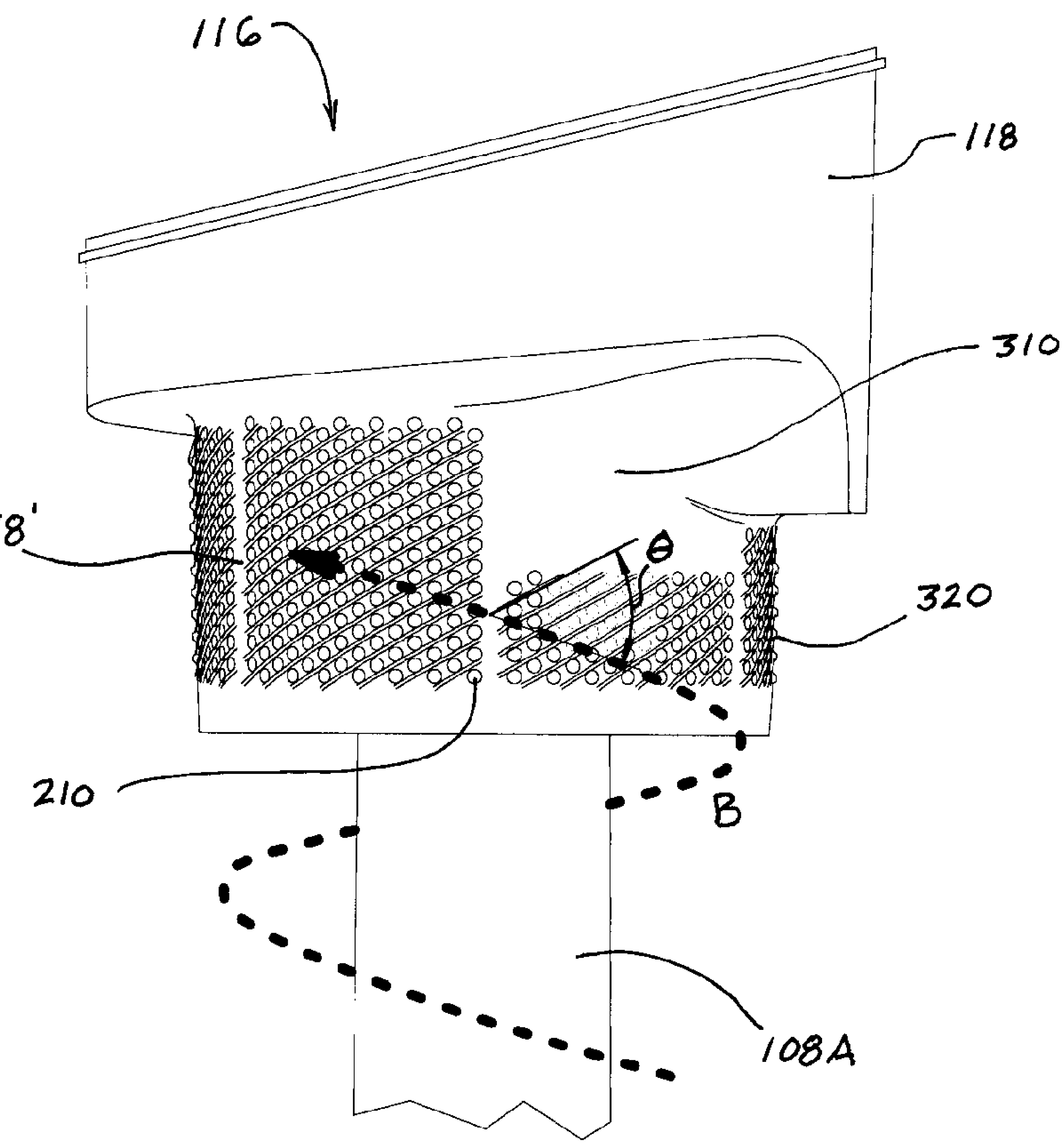


FIG. 4



CYCLONIC VACUUM CLEANER RIBBED CYCLONE SHROUD

FIELD OF THE INVENTION

The present invention relates to features for use with vacuum cleaners having a centrifugal or cyclonic air separation system. More specifically, the present invention relates to a cyclone shroud having a ribbed or textured surface.

BACKGROUND OF THE INVENTION

Cyclonic vacuum cleaners are well known in the art. Typically, a cyclonic vacuum uses a rigid cyclone container in place of a bag. The cyclone container typically is cylindrical or somewhat tapered, and includes an inlet that receives dirty air, and an outlet through which cleaned or partially-cleaned air exits. A vacuum fan is used to convey the air through the cyclone container, and the fan may be located upstream or downstream of the cyclone container. As the air passes through the cyclone container, it is directed in a cyclonic pattern to remove dirt and dust from the air flow due to the vortex motion of the cyclone. The removed dirt and dust is deposited with the lower portion of the container or directed into an auxiliary dirt collection container as it drops out of the cyclonic air flow.

It is also well known to use more than one cyclone in the air flow path, and multiple series and/or parallel cyclones may be used in a single vacuum cleaner. Further, filtration features, such as shrouds and other kinds of filter, may be used within the air flow path, either within the cyclone or cyclones, or upstream or downstream of them. For example, a shroud may be used to direct the air flow within the cylindrical container into a vortex, and to force the airflow to change directions to remove particles by inertia. Shrouds may come in various shapes and sizes, and it is known to provide cylindrical shrouds, conical shrouds, frustoconical shrouds, and shrouds having other shapes. Shrouds may be formed with a mesh type screen, circular perforations, or other apertures or openings to allow air to pass through the shroud while filtering out larger particles. Depending on the application, the perforations may be specifically sized to prevent certain size dust and dirt particles from passing through, while providing relatively little impediment to the airflow, and different hole geometries have been used in efforts to improve air/dirt separation within a vacuum cleaner.

It is also well known that cyclone shrouds may be provided in the form of microporous filters. Indeed, a shroud is simply a filter having large pores. Filters used in cyclones may comprise any of various useful types and shapes, such as pleated, foam, ultra fine, HEPA, ULPA, and so on. Combinations of shrouds and/or microporous filters having various filtration sizes may be used in any number of combinations within or in conjunction with a vacuum cleaner cyclone separator.

Cyclone shrouds and other kinds of filter also may have other features to enhance airflow or dirt separation. For example, a feature such as a flow reversing lip may be added to a shroud. Flow reversing lips typically are located circumferentially around the bottom lip of the shroud and extend downward, at an angle, or radially, to obstruct the airflow flowing from below the shroud up to the shroud surface. Such flow reversing lips may enhance dirt separation, prevent larger objects from being lifted into contact with the shroud's perforated surface, or provide other benefits. Exemplary cyclonic vacuums having shrouds, reversing lips, filters, and other filtration and flow controlling devices are described in U.S. Pat. Nos. 5,145,499; 5,893,936; 6,910,245; and 7,222,392, which references are incorporated herein.

While various prior art devices, such as those described above, have been used, there exits a need to provide alternatives to such devices.

SUMMARY OF THE INVENTION

In a first exemplary aspect, the present disclosure provides a cyclone separator for a vacuum cleaner. The cyclone separator has a cyclone chamber and a filter shroud. The cyclone chamber has an air inlet and an air outlet, and is adapted to direct an airflow into a cyclonic pattern to remove a first amount of debris from the airflow. The filter shroud is located within the cyclone chamber and separates the air inlet from the air outlet. The filter shroud includes an air-pervious filter surface adapted to allow the airflow to pass from the air inlet to the air outlet and remove a second amount of debris from the airflow. One or more protrusions are associated with the filter surface. The one or more protrusions are configured and dimensioned to direct at least a portion of the airflow passing generally parallel to the filter surface away from the filter surface before passing through the filter surface.

In another exemplary aspect, the present disclosure provides a dirt collection assembly for a vacuum cleaner. The dirt collection assembly has a cyclone chamber, a filter shroud, and a dirt collection chamber. The cyclone chamber has a generally cylindrical sidewall, an air inlet and an air outlet, and is adapted to direct an airflow into a cyclonic pattern to remove a first amount of debris from the airflow. The filter shroud is located within the cyclone chamber and separates the air inlet from the air outlet. The filter shroud includes an air-pervious filter surface adapted to allow the airflow to pass from the air inlet to the air outlet and remove a second portion of debris from the airflow. One or more protrusions are associated with the filter surface, and are configured and dimensioned to direct at least a portion of the airflow passing generally parallel to the filter surface away from the filter surface before passing through the filter surface. The dirt collection chamber is adapted to receive the first amount of debris and the second amount of debris.

In a third exemplary aspect, the present disclosure provides a method for removing debris from an airflow. The method may involve: introducing an airflow through an inlet into a cyclone chamber; causing the airflow to spiral downward through the cyclone chamber (thus forming an outer cyclone column located adjacent an outer wall of the cyclone chamber); causing the airflow to move radially inward towards a center axis of the cyclone chamber; causing the airflow to spiral upward through the cyclone chamber (thus forming an inner cyclone column located radially inward of the outer cyclone column); passing at least a first portion of the airflow forming the inner cyclone column across a filter surface; and passing the first portion of the airflow over a series of obstructions extending from the filter surface before passing the first portion of the airflow through the filter surface.

The recitation of this summary of the invention is not intended to limit the claimed invention. Other aspects, embodiments, modifications to and features of the claimed invention will be apparent to persons of ordinary skill in view of the disclosures herein. Furthermore, this recitation of the summary of the invention, and the other disclosures provided herein, are not intended to diminish the scope of the claims in this or any prior or subsequent related or unrelated application.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is described in detail with reference to the examples of embodiments shown in the following figures in which like parts are designated by like reference numerals.

FIG. **1** is a side plan view of a dirt collection assembly incorporating features of the present invention.

FIG. **2** is a cutaway side view of the exemplary dirt collection assembly of FIG. **1**.

FIG. **3** view of the inlet structure of the exemplary dirt collection assembly of FIG. **1**.

FIG. **4** is a view of a filter shroud of the exemplary dirt collection assembly of FIG. **1**.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTIONS

The present disclosure provides numerous inventive features relating to a textured shroud for use in a vacuum cleaner separation system. Various features and alternative embodiments of the invention are described with reference to their exemplary use in certain embodiments, but it will be readily appreciated that the features could alternatively be incorporated into other embodiments of vacuum cleaner dirt separation systems. The invention includes these and other variations, as will be appreciated by persons of ordinary skill in the art in view of the present disclosure. Furthermore, the various features described herein may be used separately from one another or in any suitable combination. The present disclosure illustrating various exemplary embodiments is not intended to limit the invention in any way.

An exemplary embodiment of the invention is illustrated in FIGS. **1-4**, which generally illustrate a dirt collection assembly **100** for an upright, canister, central or any other type of vacuum cleaner. The dirt collection assembly **100** in the illustrated embodiment is constructed such that it can be attached to and removed from a vacuum cleaner (not shown) as a complete unit, but it will be appreciated that all or portion of the dirt collection assembly may be permanently attached to the vacuum cleaner in other embodiments.

The exemplary dirt collection assembly **100** includes a cup **102** a filter cover **114**, and various internal features. The cup **102** is depicted as being generally cylindrical, with a transparent or partially-transparent sidewall **103** having inner and outer surfaces. It will be appreciated that the cup **102** may be made from multiple assembled sidewalls or a single molded structure, and may have any suitable overall exterior and interior shape. The cup **102** has a bottom wall **106** located at or near the bottom of the sidewall **103**, to form an enclosed cup-like shape.

The cup **102** has an inlet **104** and an outlet **108**. The inlet **104** is adapted to mate with a dirty air passage (not shown) to convey dirty air into the cup **102**. The dirty air has dirt and/or debris entrained therein, which is drawn from a surface being cleaned by a conventional vacuum fan (not shown) located upstream or downstream of the inlet **104**. The dirty air passage may be connected to a conventional vacuum cleaning device, such as a floor nozzle, cleaning wand nozzle, a vacuum tool such as a brush, or the like. The exemplary inlet **104** passes through the cup sidewall **103** near the upper edge of the cup **102**, and may be oriented to direct the airflow in a tangential direction to the inner surface of the cup **102**. In other embodiments, the inlet **104** may be located in a lid covering the top of the cup **102**, provided through the bottom of the cup **102**, or located elsewhere, as will be understood and appreciated by persons of ordinary skill in the art in view of the present disclosure. In addition, the inlet **104** may be provided with (or work in conjunction with) one or more baffles or other structures to direct the air in a tangential or cyclonic manner into the cup **102**. Such features are known in the art, and may be desirable, for example, if the inlet **104** directs the incoming dirty air generally perpendicularly into the cup **102**, to help initiate a tangential airflow within the cup.

The outlet **108** of the exemplary embodiment passes through the bottom wall **106** of the cup **102**. As shown in FIGS. **1** and **2**, the outlet **108** passes approximately through the center of the bottom wall **106**, but it may be offset from the center of the cup **102** by some distance, such as a distance of about 0.125 to about 1.00 inches. In other embodiments, the outlet **108** may pass through the sidewall **103**, or through the filter cover **114** (or any other kind of lid over the top of the cup **102**). Such variations are known in the art. The outlet **108** provides a path for air to exit the dirt collection assembly **100**, and may comprise a simple hole through the cup **102**, or it may include an extension, such as outlet tube **108**A. The outlet **108** fluidly attaches to the inlet of a vacuum fan or to the atmosphere, depending on whether the vacuum fan is downstream or upstream of the dirt collection assembly **100**, respectively. The outlet **108** may have an outlet seal **204** around its circumference to provide an airtight passage to downstream components, and such a seal may be located at the bottom of the outlet tube **108**A, if such a tube is used. The outlet seal **204** may be made from a suitable material, such as rubber, silicone, or plastic.

The bottom wall **106** may have a pivoting trap door **110** through which contents of the cup **102** can be released. The exemplary trap door **110** is pivotally mounted at one side of the cup **102** by a hinge **121** and secured in sealing contact with the bottom edge of the sidewall **103** by a lower latch **122** located on the opposite side of the cup **102**. A seal **202** may be provided to help prevent dirt and air from passing between the trap door **110** and the sidewall **103**. As shown, the outlet **108** may seal against the outlet tube **108**A, such as by using an outlet seal **204** when the trap door **110** is closed. Such pivot, catch and seal arrangements are known in the art. In this exemplary embodiment, releasing the trap door **110** with the lower latch **122** provides a way to empty the cup **102** of collected dirt and dust. After opening, the trap door **110** may be closed and secured in place by the lower latch **122**. It is understood that this particular construction is not required, and other constructions are possible to provide for emptying of the cup **102**. For example, the bottom wall **106** may simply be formed as part of the sidewall **103**, and the cup **102** may be emptied by turning it over and removing the filter cover **114** and any other parts sealing the top of the cup **102**.

The cup **102** is covered by a lid, an integrally formed upper wall, or any other suitable structure to enclose or selectively cover the top of the dirt collection assembly **100**. The enclosing upper structure may be formed as part of the vacuum cleaner to which the cup **102** is attached or as part of the cup **102** itself, or it may be provided as a separate part that is removable from the vacuum cleaner with the cup **102**, as in the exemplary embodiment. These and other variations are known in the art. In the shown embodiment, the cup **102** has an upper edge **112** with a lip **112'** that provides an attachment point for a filter cover **114**. The filter cover **114** is freely attachable and detachable from the cup **102**, but it may connected to the cup **102** by a pivot, slide, or other structure that keeps the filter cover **114** and cup **102** from being completely disassembled from one another. As shown in FIG. **2**, the filter cover **114** hooks around the lip **112'** on one side of the cup **102**, and an upper latch **120** secures the filter cover **114** to the upper edge **112** of the cup **102**. The upper latch **120** comprises a simple rocker catch, as shown, or some other suitable attachment device (e.g., threaded fastener, cam lock, etc.) that holds the parts together. The filter cover **114** may include a seal (not shown) that forms an airtight seal between the filter cover **114** and the top of the cup **102**, but this is not required in all embodiments. The filer cover **114** is shown with an optional handle **114'**, which may be used to carry the cup **102** when the dirt collection assembly **100** is removed from a vacuum cleaner. The handle **114'** also may provide a leverage point for removing the filter cover **114** from the cup **102**. It will be understood that this particular construction is optional and other constructions are possible to provide a cover for the cup **102**.

A filter shroud **116** is located within the cup **102**, and fluidly located between the inlet **104** and the outlet **108**. The illustrated filter shroud **116** has an upper wall **118** that mounts to the sidewall **103**, and a generally cylindrical filter surface **118'** that extends from the upper wall **118** and is located radially inward from the inner surface of the cup sidewall **103**. The filter surface **118'** may be connected to the upper wall **118** by a generally radial wall **124**. The radial wall **124** may have a width W as shown (see FIG. **2**), and it may either be generally horizontal, or angled so that the radial wall **124** is not perpendicular to the upper wall **118** and/or the filter surface **118'**. In other embodiments, the radial wall **124** (if provided) may be otherwise contoured or configured. For example, the radial wall **124** may have a curved shape or include a curved radius where it joins the filter surface **118'** (as shown) and/or the upper wall **118**.

As shown in the Figures, the radial wall **124** also may have a ramp-like or helical shape to help direct air and debris downwardly as it rotates within the cup **102**. In the exemplary embodiment, this helical shape extends from a point at or above the top of the inlet **104** to a point towards or below the bottom of the inlet **104** as the radial wall **124** circles the cup **102**. Modifying the total ramp height (i.e., the distance between the starting point and ending point with respect to the axis of the cyclone chamber) may affect the particle separation properties of the device. For example, terminating the radial wall **124** at a point somewhere at or near the bottom of the flow path of air entering through the inlet **104**, such as in the shown embodiment, may cause the air passing around the cup **102** below the radial wall **124** to pass below the incoming air to help prevent the creation of turbulence. Variations on this shape and configuration may be provided in other embodiments.

The filter shroud **116** may be removable from the cup **102**, permanently mounted therein, or even integrally formed with the cup **102**. In the shown embodiment, the top edge of the upper wall **118** has a lip **118'** that mates with a corresponding notch **112"** located near the upper edge **112** of the cup **102**. A flexible circumferential seal **200** may be provided at the upper edge **112** of the cup **102** to help form an airtight seal between the filter shroud **116** and the sidewall **103**. The seal **200** may be made of a suitable sealing material, such as a flexible rubber or plastic. The seal **200**, as shown, provides an air tight seal between the filter shroud **116** and the upper edge **112** of the cup **102** when the filter shroud **116** is within the cup **102** (as used herein, the term "air tight" and similar terms contemplates that some marginal amount of air may pass through, particularly where a seal is worn or damaged during use). The seal **200** also (or alternatively) may seal the top of the filter shroud **116** to the bottom of the filter cover **114**. An airtight seal between the sidewall **103** and the filter shroud **116** also may be provided by forming the upper wall **118** to closely fit the inner surface of the sidewall **103**, by bonding these parts together, or by any other means. It may also be desirable or permissible to provide some amount of air leakage through this location to prevent the vacuum fan motor from overheating if the inlet **104** (or the flow path upstream of the inlet **104**) becomes obstructed.

The bottom of the filter shroud **116** is connected to the outlet tube **108**A, and an airtight seal may be formed between these parts by ultrasonically bonding them together, forming them integrally, providing a flexible gasket seal, or by simply providing a close tolerance between the parts. As explained above, the outlet tube **108**A mates with the outlet **108**. As such, the outlet tube **108**A may help to position and stabilize the filter shroud **116** within the cup **102**.

As best shown in FIG. **2**, the filter surface **118'** has a series of perforations **210** through which air can pass to travel from the inlet **104** to the outlet **108**. The perforations **210** may cover the entire filter surface **118'** or only selected portions thereof, and may have any suitable profile (e.g., round, square, etc.), shape (e.g., cylindrical, frustoconical, rounded edges, beveled edges, sharp edges, etc.), orientation (e.g., perpendicular or at an angle relative to the filter surface **118'**), size, or arrangement. In the shown embodiment, the perforations **210** are round, have uniform diameters of about 2 millimeters, beveled or rounded edges on the end facing the cup wall **103**, and extend through the filter surface **118'** in a direction generally perpendicular to the filter surface **118'**. The exemplary perforations **210** are arranged in a repeating pattern of helical rows that extend both axially with respect to the cylindrical surface centerline, and around at least a portion of the circumference of the filter surface **118'**. In other embodiments, other geometric patterns, such as square patterns (in which the perforations **210** are arranged in a repeating square pattern), or non-geometric patterns may be used instead of the shown pattern of perforations **210**. In addition, in other embodiments, the perforations **210** may be randomly distributed or arranged in a unique, non-repeating pattern. It will also be appreciated that the perforations **210** may be provided having a mix of sizes, shapes, patterns, and so on. The perforations **210** allow air to pass from the inlet **104** to the outlet **108** while preventing particles larger than the perforations **210** from passing therethrough. The general concept of perforated shroud structures is known in the art of vacuum cleaners, and any suitable alternative arrangement of perforations or shroud shape may be used.

The filter surface **118'** may include one or more portions having no or relatively few perforations **210**. In the exemplary embodiment, a solid wall portion **310** lacking perforations is provided adjacent the inlet **104**, so that incoming air does not immediately enter perforations **210**. The solid wall portion **310** also may help direct the incoming tangential flow of air towards the sidewall **103**, which may help encourage cyclonic separation by establishing airflow patterns within the cup **102**, and/or help compress incoming debris against the sidewall **103** or direct it away from the filter shroud **118'**.

A series of ribs **320** are located on the filter surface **118'**. Each rib **320** comprises a raised structure on the outer surface of the filter surface **118'**. The ribs **320** may comprise separate parts, or they may be integrally formed with the filter surface **118'**. The ribs may protrude any distance from the filter surface **118'**, but in the shown embodiment they protrude at least about 0.5 millimeters. In the shown embodiment, some or all of the ribs **320** extend in a helical manner around the circumference of the filter shroud **118'**, and generally are located between adjacent helical rows of perforations **210**. Thus, the helical rows of perforations **210** and the ribs **320** provide a repeating and alternating pattern generally over the entire filter surface **118'**, as can be seen in FIG. **3**, for example.

The ribs **320** are arranged such that they obstruct, rather than conform to the air flowing over the filter surface **118'**. As will be appreciated by persons of ordinary skill in the art, air entering the cup **102** generally will rotate tangentially and downward along the outer perimeter of the cup **102**, such as shown by arrow "A" in FIG. **1**. When the air reaches the bottom wall **106** of the cup (or any debris resting on the bottom wall **106**), it tends to reverse its vertical direction, and migrate towards the center of the cup. The air continues to rotate around the cup **102** as it returns upwards and generally along the outlet tube **108**A, and eventually arrives at the filter surface **118'**. As the air reaches the filter surface **118'**, it is still rotating in the same direction with which it entered the cup **102**, but in an upwards angular direction as shown by Arrow "B," rather than the initial downwards angular direction. In a preferred embodiment, the ribs **320** are oriented to cross the direction of the airflow adjacent the filter surface **118'** (see, e.g., FIG. **4**), either perpendicularly, or at some substantial crossing angle (e.g., as shown by angle "Θ"). An angle of about 90 to about 30 or 15 degrees, or even less, is expected to provide the benefits of the present invention, but smaller crossing angles may be used and may be ideal under some circumstances.

It has been found that the use of ribs **320** on the filter surface **118'** may provide a significant benefit by improving at least some aspects of the dirt collection assembly's performance. Without being limited to any theory of operation, it is believed that the air passes over the filter surface **118'**, and strikes the ribs **320** (or a boundary layer created by the ribs **320**), which provide an obstacle over which air must pass before it can enter the perforations **210**. This suspected motion is believed to lift objects away from the filter surface **118'**. Furthermore, the ribs **320** hold large particles away from the perforations **210**, to thereby allow air to flow into the perforations **210** along the channel between adjacent ribs **320**, even when a large object, such as a piece of paper, might by pressed against the ribs **320**. In addition to improving cyclone performance (particularly when the cup **102** is nearly full of debris), it has been found that the ribs **320** may also help prevent elongated particles such as hair and fibers from clinging to the filter surface **118'**. This may improve cyclone operating performance and make it easier to clean and maintain the filter surface **118'**.

As shown in FIG. **2**, the filter surface **118'** may be radially displaced relative to the outlet tube **108**A, and joined to it by a lower wall **220**, but in alternative embodiments, the outlet tube **108**A may be omitted, or may have the same or a larger diameter than the filter surface **118'**. In the shown embodiment, the lower wall **220** may include a downwardly-projecting annular lip **222** around its bottom circumference, or other structures to help control the airflow, improve efficiency or provide other benefits. As shown, the exemplary lip **222** may extend in a generally downward direction perpendicular to the longitudinal axis of the filter shroud **116**. This lip **222** may force the air flow to change direction, thus serving as a flow reversing lip, or otherwise alter the airflow pattern within the device as it progresses from the lower portions of the cup **102** to the filter surface **118'**. For example, the air, once it reaches the surface of the lower wall **220**, may flow radially outward to the lip **222**, which may cause it to change directions with the result being that additional debris is removed from the airflow by inertia. Alternatively, the lip **222** may create a recirculating or dead air space below the lower wall **220** that slows the air and helps remove entrained particles. Regardless of the manner or theory of operation, lips **222**, such as in the exemplary embodiment or having other shapes (for example, as a radially extending wall or a frustoconical projection) may be used with embodiments of the present invention, if desired. It will also be understood that the lower wall **220** may itself include perforations.

It will be understood that the filter shroud **116** and filter surface **118'** depicted in the exemplary embodiment are only one possible embodiment of the invention, and variations on the illustrated shape and construction will be readily apparent to persons of ordinary skill in view of the present disclosure. For example, the filter shroud **116** may be formed from a single molded piece of plastic, and it may have different shapes. Furthermore, the filter surface **118'** may have other shapes, such as a frustoconical shape, a rounded shape, or a mix of different shapes. In addition, the filter surface **118'** may comprise a screen or other filter medium (such as a conventional pleated filter, a rigid nonwoven fiber mat, a porous plastic material, or any other material suitable for filtering particles from air), and the ribs **320** may comprise a separate part that is fitted or formed over the screen or filter. In addition, the ribs **320** may be provided as an add-on part that can be attached to a pre-existing shroud or filter.

Furthermore, the illustrated filter shroud **116** may be replaced or modified, and the filter surface **118'** may be held in the dirt collection assembly **100** in other ways. For example, in other embodiments, the upper wall **118** and/or radial wall **124** may be modified, minimized or reshaped to provide other structures that hold the filter surface **118'** in position within the dirt collection assembly **100**. For example, the upper wall **118** may be omitted, and the radial wall **124** may provide the only support between the filter surface **118'** and the sidewall **103**, such as shown in U.S. Pat. No. 6,910,245. In another embodiment, the upper wall **118** and radial wall may be omitted, and the filter surface **118'** may be mounted to the filter cover **114** or other lid structure, such as shown in U.S. Pat. No. 6,558,453. In still other embodiments, the filter surface **118'** may be provided as a separate part that is mounted over an outlet tube and captured in place by a lid, such as shown in U.S. Pat. No. 6,829,804, or such a filter surface **118'** may be attached to the outlet tube such that it is not necessary to capture it in place by a lid. In still other embodiments, the filter surface **118'** may be mounted in a cyclone chamber above a removable dirt cup, in which case the combined structure formed by the cyclone chamber and the dirt cup forms the dirt collection assembly. An example of a device having the foregoing general structure is illustrated in U.S. Patent Publication No. 2005/0138763. The disclosures of the foregoing references are all incorporated herein.

A filter **230** may be located within the filter shroud **116**, as illustrated in FIG. **2**. The filter **230** is fluidly located in the air path between the filter shroud **116** and the outlet **108** so that air must pass through the filter **230** before reaching the outlet **108**. The filter **230** is arranged such that air passes radially inward through the cylindrical filter wall, but other filter shapes and airflow patterns may be used. The filter **230** may mounted in the dirt collection assembly **100** in any suitable way. For example, as shown, the filter **230** may be mounted upon a filter stem **232**, which is connected to the top of the outlet tube **108**A or formed integrally therewith. The filter **230** has a circular bottom opening **234** that fits over the filter stem **232**, or alternatively, the filter **230** may have a lower extension that fits within the filter stem **232** or outlet tube **108**A or outlet **108**. When installed, the filter **230** seals against the filter stem **232** such that air passing to the outlet **108** must pass through the filter **230**. While this construction is preferred, it will be appreciated that other constructions are possible. For example, in other embodiments, a filter stem may not be provided.

The filter **230** preferably is securely retained on the filter stem **232**. For example, the filter **230** may be fitted to the filter stem **232** by a friction fit, a bayonet fitting, a fastener, or by other attachment means. In the shown embodiment, the filter **230** is held in place on the filter stem **232** by a filter seal **236** and upper filter retainer **238** (which may be provided as part of the filter cover **114**), that press and/or capture the filter **230** in place. The filter seal **236** and the upper filter retainer **238** press the filter **230** in place, and may provide an airtight seal over the top of the filter. To this end, the filter seal **236** may be made of an appropriate material, such as rubber, silicone, or plastic, that seals against and presses down on the filter **230**. The upper filter retainer **238** may be formed as part of the inner surface of the filter cover **114**, or provided as a separate part that is attached to the filter cover **114** or otherwise mounted in place. If desired, the filter **230** may be attached to the filter cover **114** to be removed therewith, or it may remain in place on the filter stem **232** when the filter cover **114** is removed, as in the shown embodiment.

The filter **230** may be made of any suitable material, such as a pleated paper filter, a flexible foam filter, a porous plastic filter, and so on, or a combination of materials. The filter material can be such as to remove fine particulate matter from the air flow as it passes through the filter **230**, and preferably is selected to complement the filtration performance of the filter surface **118'** (e.g., selected to remove smaller particles that are more likely to pass through the filter shroud **118'**). The filter **230** may be a HEPA ("High Efficiency Particulate Air") type filter or any other suitable grade of filter. Different types of filters may be interchangeably used based upon different air quality needs. A handle **230**A may be mounted on the filter **230** to facilitate its installation and removal, as known in the art.

The air flow path of an exemplary embodiment of the dirt collection assembly will now be described. Dirty air containing dirt and dust particles of varying sizes and types is conveyed by a conventional vacuum fan and duct system to the dirt collection assembly inlet **104** to the dirt collection assembly **100**. The dirty air passes through the inlet **104**, enters the cup **102**, and is tangentially directed around the inner wall of the cup **102**. This tangential flow causes the air to follow the inner surface of the cup **102**. The inlet **104** is located below the radial wall **124** of the filter shroud **116**, and the radial wall **124** helps direct the airflow downward along the inner surface of the cup **102**. As the air flows downward along the cup **102**, a cyclonic vortex forms. The generally round, frustoconical, or cylindrical shape of the cup **102** may aid in the formation of the cyclone. The air flows downward until it reaches the bottom wall **106**. Upon reaching the bottom wall **106**, the air flows radially inward, and then upward along the outer surface of the outlet tube **108**A. At this point, two cyclonic flows may simultaneously exist in the cup **102**. One is a downward cyclonic flow along the inner surface of the cup **102**, forming a first cyclonic column. The second is an upward cyclonic flow along the outer surface of the outlet tube **108**A, forming a second cyclonic column moving vertically opposite to the first cyclonic column. The cyclonic flow, coupled with the change in direction, may force dirt and dust particles to exit the air flow. Upon exiting the air flow, the dirt and dust particles may be begin to settle upon the bottom wall **106** of the cup **106**.

Returning to the upward cyclonic flow along the outer surface of the outlet tube **108**A, the air will flow upward until it contacts the lower wall **220** of the filter shroud **116**. Once it reaches the lower wall **220**, the air will flow radially outward. As noted above, the flow reversing lip **222** may help remove additional particles or prevent particles from rising upward with the inner cyclone flow. Upon reaching the outer edge of the flow reversing lip **222**, the air flows upward over the filter surface **118'**, preferably still retaining a cyclonic movement as it does so. Upon reaching the filter surface **118'**, the air will begin passing through the perforations **210** and into the interior of the filter shroud **116**. The air flow through the perforations **210** may be generally perpendicular to the longitudinal axis of the filter shroud **116**. Before passing through the perforations **210**, the airflow encounters the ribs **320**, which may help improve the cyclone performance in one or more respects, as explained above. Particles that travel to the filter surface **118'** and can not pass through the perforations **210** eventually fall out of the airflow (either during operation or when the airflow is stopped), and are collected in the cup **102**. Some particles may cling to the filter surface **118'**, but it has been found that the ribs **320** reduce the likelihood of such occurrences.

Upon reaching the interior of the filter shroud **116**, the air rises and encounters the filter **230**. The filter seal **236** and the upper filter stem **234** prevent the air from flowing over the top or under the bottom of the filter **230**, leaving the only air path through the filter medium. The filter **230** removes additional dirt and dust particles from the air. Once the air passes through the filter **230** it travels downward through the upper filter stem **234**, outlet tube **108**A, and eventually the outlet **108**. The vacuum fan may be downstream of the outlet **108** or upstream of the inlet **104**, or even contained within the dirt collection assembly **102**, such as by being mounted within the filter shroud **116** or outlet tube **108**A. After exiting the outlet **108**, the air eventually exits the vacuum cleaner and is exhausted to the atmosphere. One or more additional filters may, of course, be positioned at or after the outlet **108** to further filter the air as it exits.

The present disclosure describes a number of new, useful and nonobvious features and/or combinations of features that may be used alone or together with cyclonic vacuum cleaners and possibly other kinds of suction cleaning devices. The embodiments described herein are all exemplary, and are not intended to limit the scope of the inventions in any way. It will be appreciated that the inventions described herein can be modified and adapted in various ways and for different uses, and all such modifications and adaptations are included in the scope of this disclosure and the appended claims.

What is claimed is:

1. A cyclone separator for a vacuum cleaner, the cyclone separator comprising:

a cyclone chamber having an air inlet and an air outlet, the cyclone chamber being adapted to direct an airflow into a cyclonic pattern to remove a first amount of debris from the airflow;

a filter shroud located within the cyclone chamber and separating the air inlet from the air outlet, the filter shroud comprising an air-pervious filter surface adapted to allow the airflow to pass from the air inlet to the air outlet and remove a second amount of debris from the airflow; and

one or more protrusions associated with the filter surface, the one or more protrusions being configured and dimensioned to direct at least a portion of the airflow passing generally parallel to the filter surface away from the filter surface before passing through the filter surface;

wherein the filter surface is generally cylindrical or frustoconical, and the one or more protrusions comprise a plurality of ribs extending in a generally helical pattern around the filter surface, the ribs being oriented generally perpendicular to the portion of the airflow passing generally parallel to the filter surface.

2. The cyclone separator of claim **1**, wherein the filter surface comprises a perforated surface having a plurality of discrete holes therethrough.

3. The cyclone separator of claim **1**, wherein the plurality of ribs are arranged at an angle of about 15 degrees to about 60 degrees with respect to a plane orthogonal to a central axis of the filter surface.

4. The cyclone separator of claim **1**, wherein the one or more protrusions extend at least about 0.5 millimeters from the filter surface.

5. The cyclone separator of claim **1**, wherein the filter surface comprises a perforated surface having a plurality of discrete holes therethrough, and the plurality of discrete holes are arranged in a series of helical rows located adjacent the plurality of ribs.

6. The cyclone separator of claim **5**, wherein the perforations have a diameter of about 2 millimeters.

7. The cyclone separator of claim **1**, wherein the one or more protrusions are formed integrally with the filter surface.

8. The cyclone separator of claim **1**, wherein the one or more protrusions comprises a plurality of parallel ribs that are attachable over the outer surface of the filter surface, and the filter surface comprises a pleated filter.

9. A dirt collection assembly for a vacuum cleaner, the dirt collection assembly comprising:

a cyclone chamber having a generally cylindrical sidewall, an air inlet and an air outlet, the cyclone chamber being adapted to direct an airflow into a cyclonic pattern to remove a first amount of debris from the airflow;

a filter shroud located within the cyclone chamber and separating the air inlet from the air outlet, the filter shroud comprising an air-pervious filter surface adapted to allow the airflow to pass from the air inlet to the air outlet and remove a second portion of debris from the airflow;

one or more protrusions associated with the filter surface, the one or more protrusions being configured and dimensioned to direct at least a portion of the airflow passing generally parallel to the filter surface away from the filter surface before passing through the filter surface; and

a dirt collection chamber adapted to receive the first amount of debris and the second amount of debris;

wherein the filter surface is generally cylindrical or frustoconical, and the one or more protrusions comprise a plurality of ribs extending in a generally helical pattern around the filter surface, the ribs being oriented generally perpendicular to the portion of the airflow passing generally parallel to the filter surface.

10. The dirt collection assembly of claim **9**, wherein the plurality of ribs are arranged at an angle of about 15 degrees to about 60 degrees with respect to a plane orthogonal to a central axis of the filter surface.

11. The dirt collection assembly of claim **9**, wherein the filter surface comprises a perforated surface having a plurality of discrete holes therethrough, and the plurality of discrete holes are arranged in a series of helical rows located adjacent the plurality of ribs.

12. The dirt collection assembly of claim **9**, wherein the filter surface is generally cylindrical or frustoconical, and the dirt collection assembly further comprises a filter located downstream of the filter surface, the filter being adapted to remove a third amount of debris from the airflow.

13. The dirt collection assembly of claim **12**, the one or more protrusions comprise a plurality of ribs extending in a generally helical pattern around the filter surface, the ribs being oriented generally perpendicular to the portion of the airflow passing generally parallel to the filter surface.

14. The dirt collection assembly of claim **12**, wherein the filter shroud comprises an upper wall extending generally radially from an end of the filter surface to a location adjacent the cyclone chamber sidewall to seal an upper end of the cyclone chamber and the filter is located at least partially within a volume defined by filter surface.

15. The dirt collection assembly of claim **14**, wherein the filter is enclosed between the filter shroud and a lid, the lid being adapted to press the filter against the filter shroud.

16. The dirt collection assembly of claim **9**, wherein the inlet passes through the cyclone sidewall.

17. The dirt collection assembly of claim **9**, wherein the dirt collection chamber comprises a portion of the cyclone chamber located below an end of the filter shroud.

18. The dirt collection assembly of claim **17**, wherein the dirt collection chamber comprises a bottom wall, and the outlet passes through the bottom wall.

19. A method for removing debris from an airflow, the method comprising:

introducing an airflow through an inlet into a cyclone chamber;

causing the airflow to spiral downward through the cyclone chamber, thus forming an outer cyclone column located adjacent an outer wall of the cyclone chamber;

causing the airflow to move radially inward towards a center axis of the cyclone chamber;

causing the airflow to spiral upward through the cyclone chamber, thus forming an inner cyclone column located radially inward of the outer cyclone column;

passing at least a first portion of the airflow forming the inner cyclone column across a filter surface; and

passing the first portion of the airflow over a series of obstructions extending from the filter surface before passing the first portion of the airflow through the filter surface;

wherein the first portion of the airflow is traveling in a first helical direction with respect to the center axis, and the series of obstructions comprises a plurality of ribs extending in a second helical direction with respect to the center axis, and the first helical direction and the second helical direction have a crossing angle of at least about 15 degrees.

20. The method of claim **19**, wherein the series of obstructions are arranged generally perpendicular to a direction in which the first portion of the airflow is moving.

21. The method of claim **19**, wherein the crossing angle is at least about 60 degrees.

22. The method of claim **19**, wherein the first helical direction and the second helical direction are generally perpendicular.

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